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(U) The magazine air temperature records from nuclear-powered and diesel-powered submarines have been statistically analyzed to obtain the probable thermal exposure to be found on these types of boats. The information is divided into the temperature expectancies for the two submarine classes because of the possibility that thermally they may be dissimilar. Effort has been made to eliminate information from compartments influenced by the engine room. This report includes more than 13,000 data points from four boats. The boats were assigned to the First, Second, Sixth, and Seventh Fleets from 1964 through 1969.

NWC TP 4824
Part 4

Thermal Exposure of Ammunition on Board Ship Part 4. Submarines

by
Sakaye Matsuda
and
Howard C. Schafer
Range Department

AUGUST 1984

NAVAL WEAPONS CENTER
CHINA LAKE, CALIFORNIA 93555

Naval Weapons Center
AN ACTIVITY OF THE NAVAL MATERIAL COMMAND

FOREWORD

This report presents results of an investigation to determine the valid shipboard thermal environment of ammunition. This work was conducted by the Naval Weapons Center, China Lake, and supported by the Naval Sea Systems Command under NAVSEA Task 63X2/81013/206/1.

This part, Part 4, covers the probable thermal exposure to be found on submarines. The previously published volumes cover cruisers/large destroyers (Part 1), aircraft carriers (Part 2), and ammunition ships (Part 3).

This report has been reviewed for technical accuracy by Mr. W. W. Parmenter.

Approved by
R. V. BOYD, *Head*
Range Department
15 August 1984

Under authority of
K. A. DICKERSON
Capt., USN
Commander

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CONTENTS

INTRODUCTION

An important factor in designing a ship-launched weapon is the environmental temperature range the weapon will experience during storage and transportation. As part of a larger program aimed at determining the stockpile-to-target environments that will be experienced by ship-launched weapons, a study was undertaken to define the thermal regime as it pertains to submarine carry and storage.

Recording of the maximum and minimum air temperatures in each magazine on board every ship in all fleets has been required for years. This requirement, however, was strictly for safety; the records were usually retained on board the ship for only 1 or 2 years and then destroyed. At the request of the Naval Weapons Center (NWC), the Chief of Naval Operations in 1967 instructed all Fleet elements to send their obsolete magazine records to NWC for use in this project. Ships from all numbered fleets, including the Sixth and Seventh Fleets, responded to this request.

The data received were divided into logical study units on the basis of ship type, and these categories of data were analyzed for later reporting of results. The information on frigates (cruisers and large destroyers), aircraft carriers, and ammunition ships has been analyzed; results were reported in Parts 1, 2, and 3, respectively, of this report series. This volume, Part 4, presents the results of analyzing the data on submarines. These results provide a data base on thermal conditions of submarines for use as design criteria for submarine-based weapons. Eventually, all ship classes may be covered in similar reports detailing storage temperatures for a particular class as the need is expressed.

More than 13,000 maximum and minimum temperature data points collected from all types of compartments and lockers on all appropriate levels of both nuclear-powered and diesel-powered submarines have been integrated into this report. The data collection time frame for each boat ranged from a few months to years. Some of these submarines are no longer in service; however, the data are considered valid since all ammunition compartment temperatures tend to describe a very narrow band of exposure. Also, the data on these obsolete boats would probably detail any thermal differences that would exist in future submarine design, if such tend to exist. An engineering judgment was made, on the basis of the similar results found in Parts 1, 2, and 3 of this report series (covering many ship classes), that data from more submarines would only be superfluous.

A complete definition of the extreme temperature circumstances is not provided since the exact day-by-day positions of the submarines are not known. Therefore, it is possible that, in spite of the mass of data presented, a minute chance of exposure to less moderate temperatures could exist. Also, there was no control over submarine deployment or of the personnel actually recording the individual temperature readings.

The lack of craft location information for a given day does not invalidate the data obtained, since a correlation was made. In a separate study, the surface temperature of the antisubmarine rocket (ASROC) missile was investigated.[1,2] In the correlation, the recorded sea water temperature was compared with the minimum recorded ASROC motor temperature for the same day. The resulting readings were within a few degrees of each other. Since the data were from ships assigned to the Seventh Fleet, and this Fleet's area of interest is the Western Pacific, a good guess can be made as to the location of the ship, given the month and minimum compartment temperatures.

As indicated in References 1 and 2, the Western Pacific could be the warmest area in which U.S. ships would need to be deployed. When considering the cold-extreme situations, there is a logical self-limiting factor. For instance, none of the submarines providing data were in the Beaufort Sea during winter. This sea is ice choked in winter and a surfaced submarine would quite possibly be stuck in the ice until the next summer. A submarine sailing under the ice pack would never experience a temperature less than a minimum 27°F water temperature.

As stated above, the data presented herein did not permit the exact correlation of boat location with the recording of a given temperature. However, these data indicate that boats herein included were under way in the North Atlantic during winter and in the West Pacific during the tropical hot season. Therefore, it is safe to assume that more severe ammunition exposure during this portion of the factory-to-target sequence will be nonexistent to rare. Based on these considerations, the response temperatures presented herein for submarine-carried ordnance and materiel have a highly probable chance of occurrence.

---

[1] Naval Weapons Center. *Launcher Environment of the ASROC Motor. Part 1. Motor Wall Temperature*, by C. A. Taylor and H. C. Schafer. China Lake, Calif., NWC, June 1967. (NWC TP 4349, Part 1, publication UNCLASSIFIED.)

[2] ------. *Launcher Environment of the ASROC Motor. Part 2. Deck Magazine Temperatures*, by C. A. Taylor and H. C. Schafer. China Lake, Calif., NWC, November 1969. (NWC TP 4349, Part 2, publication UNCLASSIFIED.)

DATA HANDLING

The raw data were received from the submarines in temperature logbooks. These records identified the month, day, and year the temperatures were recorded as well as the magazine or compartment of data origin.

These raw data were keypunched, reduced, tabulated, and plotted to yield meaningful statistics and significant points of interest for submarine magazines.

The processing of the raw data was accomplished as described in Appendix A.

CLASSIFICATION

The submarines used as the thermal measurement matrix for this report were chosen at random from the many classes of fleet underwater units. Two representative samples were chosen from each of the two principal classes of submarine: nuclear-powered and diesel (fossil fuel)-powered boats.

The nuclear-powered boats are of the skipjack class of fast attack submarines. Jane's[3] indicates that the physical aspects of this class are 3,075 to 3,500 tons displacement, 30-foot draft, and 251 feet in length; a crew of 98 is typical. The representatives of the class from which data were derived for this report were the U.S.S. *Scamp* (SSN 588), Figure 1, and the U.S.S. *Snook* (SSN 592), Figure 2.

The diesel-powered boats are represented by the Guppy 1A type attack submarines. The representatives of this class from which data were derived for this report are the U.S.S. *Chopper* (SS 342), Figure 3, and the U.S.S. *Sea Robin* (SS 407), Figure 4. According to Jane's,[3] these two boats were delivered to the fleet in 1944, and therefore are representative of advanced submarine design for that era. The physical characteristics, as listed in Jane's,[3] are 1,870 to 2,440 tons displacement, 17-foot draft, and 308 feet in length, with a complement of 84 men.

These two classes of submarines seem to fairly well represent the overall spread of the U.S. Navy submarine fleet. In essence, the other units are longer, and in some instances of deeper draft. In general, however, if a correlation in the thermal response of the magazine compartments of these candidate classes is found, it can be applied even to the new Trident submarines.

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[3] *Jane's Fighting Ships*, edited and compiled by Raymond V. B. Blackman.

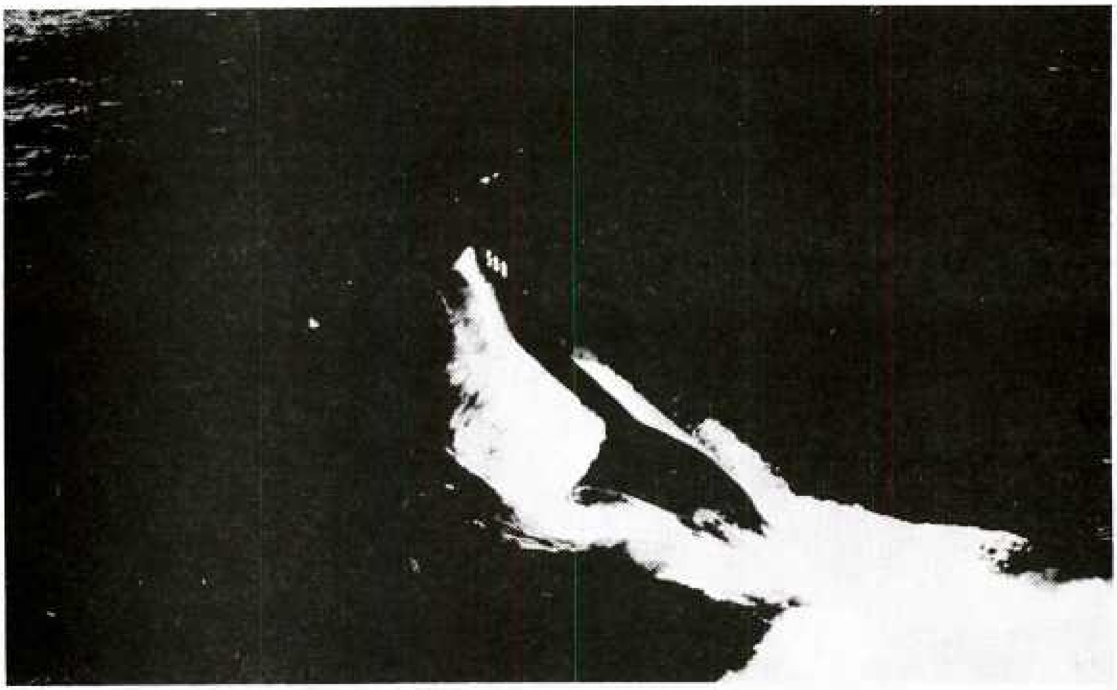

FIGURE 1. U.S.S. *Scamp*, SSN 588.

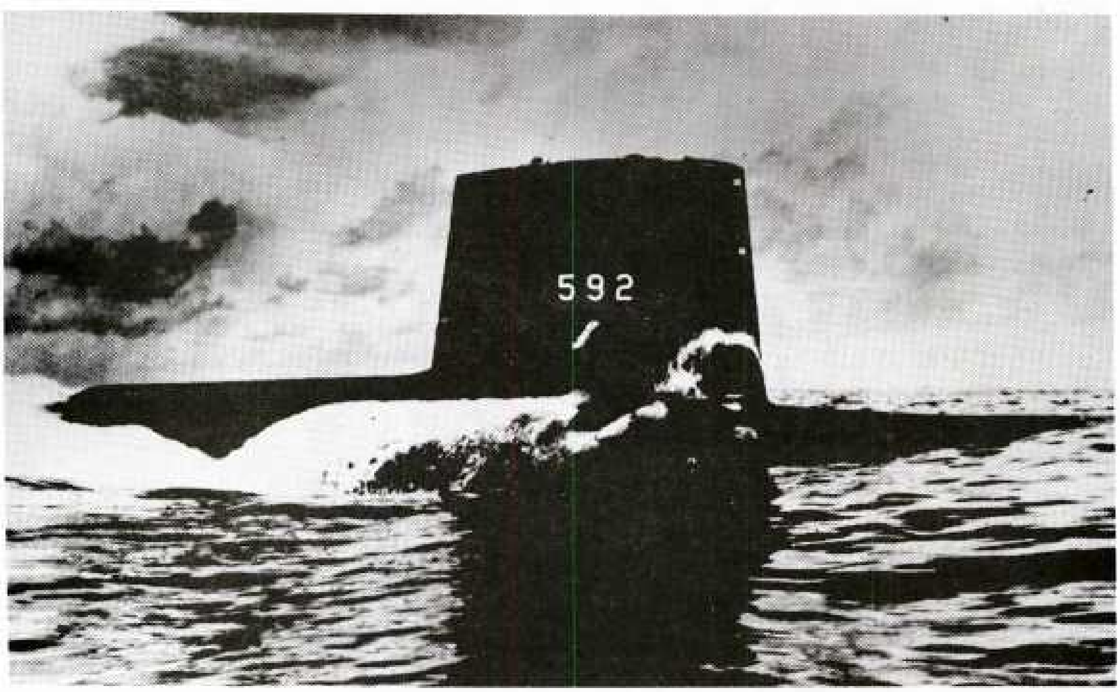

FIGURE 2. U.S.S. *Snook*, SSN 592.

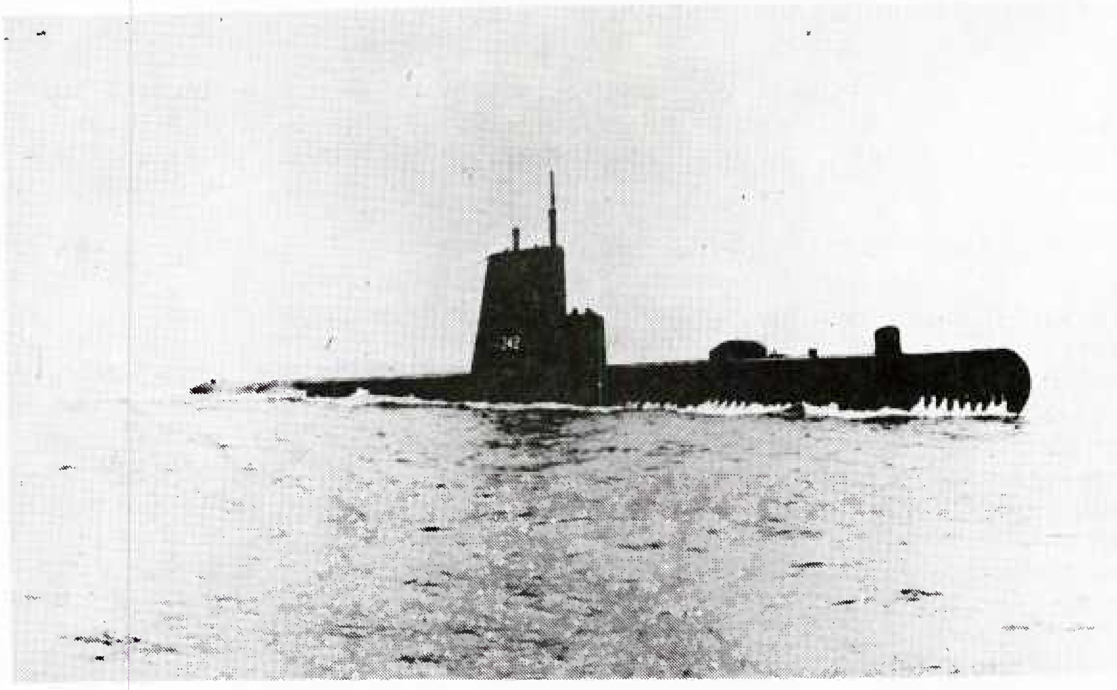

FIGURE 3. U.S.S. *Chopper*, SS 342.

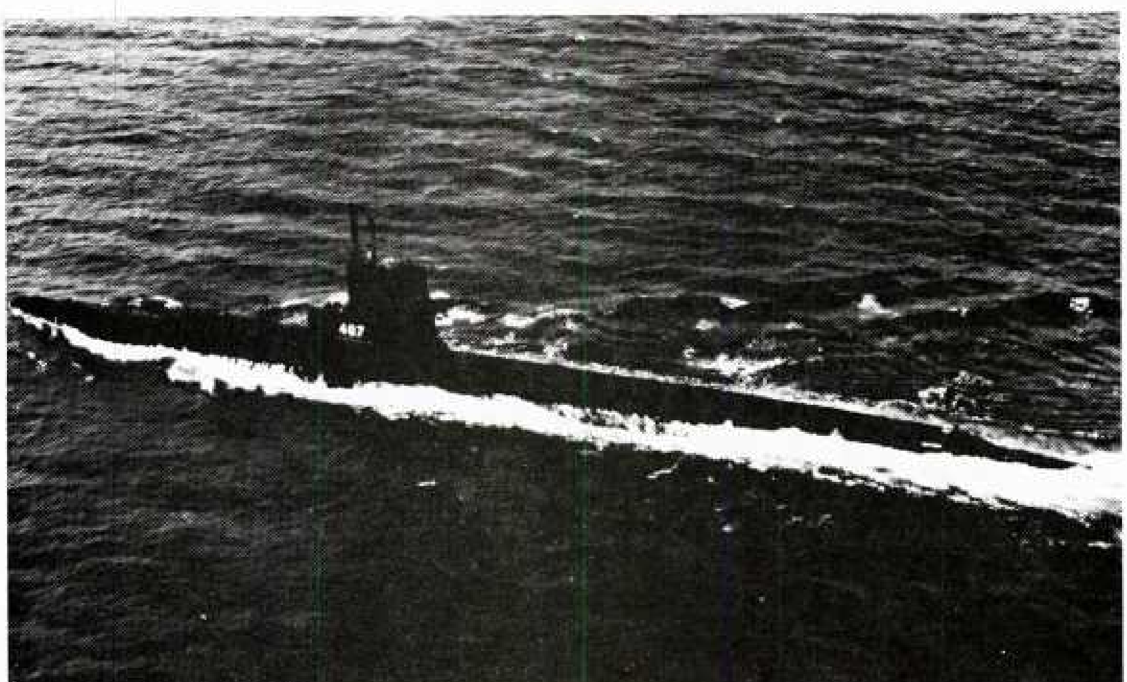

FIGURE 4. U.S.S. *Sea Robin*, SS 407.

SUBMARINE OCEAN CONTEXT

Although the author is not an authority on submarine tactics and fleet use, some fundamentals of historical and physical use of submarines should provide insight into the probable thermal regime inside a given boat.

The first advantageous physical circumstance is that submarines are built with a low on-the-surface silhouette. That means that, whether they are surfaced or submerged, the thermal heat sink called the ocean is of overriding importance to the thermal stability of any enclosed materiel. The thermal low temperature limit of liquid-state oceans is between 27°F and 32°F depending on the salt content of the water. Even under the polar ice cap the water is no colder than this. Therefore, the ordnance or materiel enclosed in the pressure hull of a submarine would not be exposed to a lower temperature. The high temperature envelope value for ordnance and materiel response can be addressed in a like manner. The record high sea temperatures are found in the Persian Gulf. These waters are reputed to have an area in them in which 98°F was recorded. It turns out that this is in the shallows, over a geologic formation noted for releasing "geologic heat." Submarine personnel have stated that submarine operations in such shallows as the Persian Gulf would be suicide. This information has been verified by personnel in the antisubmarine warfare service, who indicate that their dream is to catch a submarine in such a situation. That would leave tropical waters of 85°F or less as being the precursor of a hot thermal soak situation.

It has been proposed that a submarine will get hottest when exposed to the tropical sun while in dry dock in many tropical and semitropical locations. This is very true. Measurements done in the 1960s showed extremely high temperatures in these situations. As far as ordnance or the majority of expendables is concerned, this "fact" is of miniscule concern. It is Navy policy to off-load munitions before a ship goes in for repair or overhaul, since supplies tend to get in the way, especially in the cramped quarters of a submarine. (A similar logic could be offered for electronics or other submarine carried materiel. There is not much need for offensive, defensive, or liaison transmission or reception in a dry-dock situation. True, these units may be checked out, but this will be done by personnel trained in repair and checkout procedures who will probably know better than to mishandle them. Therefore, it would not seem logical to design an item of materiel for in-specification performance while the submarine is in dry dock.)

RESULTS

During this investigation, 13,854 data points were collected on the four boats covered. These data represent a composite of the 6 years from

1964 through 1969. The types of boats providing these data can be arbitrarily divided into two groups according to hull design and characteristics: World War II design diesel boats (the *Chopper* and *Sea Robin*) and nublear-propulsion submarines (the *Scamp* and *Snook*). The following discussion indicates that for thermal design purposes, as far as the ordnance (and probably all appended materiel in general) in concerned, a submarine is a submarine. It will be shown that the thermal exposure on board submarines is truly moderate, and a function of both sea water temperature and human comfort.

The data for the diesel-powered boats are shown in Figure 5. Figure 5 consists of a line depicting a total temperature range of 44 to 90°F. The top half of the curve approximates the shape of a gaussian display. The bottom half looks nearly gaussian, though skewed toward the cold temperatures. The mean temperature value of 75°F would seem about right for U.S. Navy ship use. (A review of Parts 1, 2, and 3 of this report series indicates that the range of mean ship ammunition temperatures is around 70 to 75°F.) The bottom half of the curve is interesting. About 25% of the data indicate a submarine interior temperature of 67°F or less. This seems somewhat chilly in physiological terms. However, one may remember that, in all the old submarine films from World Wars I and II, the sailors all wore bulky knitted sweaters under their shirts. That is only a popular indication, but a recognizable one, that cold is more the order of the day than warm.

The nuclear submarine temperature display is shown in Figure 6. The curve shape is different from that of Figure 5, in that the top half is skewed more over to the warm domain. The envelope temperatures for Figure 6 are 45 to 100°F, and the mean temperature is shown as about 74°F. In Figure 6 the temperature spread around the mean is much more balanced than was the case with Figure 5. Therefore, it would seem that the "fuel infinite" situation aboard a nuclear-powered submarine may have led to the more generous use of on-board space heaters when it was damp and chilly. Also, this space heater use seems to indicate the same "human comfort" phenomenon that has been seen in aircraft cockpit temperature measurements. It would seem that people like the temperature they are used to, no matter what it might be. As an example, a temperature of 70°F seems "cold" if the springtime or summer day is about 85°F or 90°F. Conversely, in the arctic, when the air temperature is hovering around -35°F that same 70°F is much too "hot." It would be projected that, during the winter, the comfort temperature would be less than 75°F; and during the summer more than 75°F.

Figure 7 is the combination of Figures 5 and 6. It includes all the data from both diesel and nuclear submarines. It is the author's opinion that this figure is probably very representative of the thermal regime inside a submarine. It is recommended that this data display be used as the basis of any thermal criteria for submarine-launched or -carried materiel. To all intents and purposes, Figure 7 is the data display that is most representative of the thermal regime inside a submarine. From

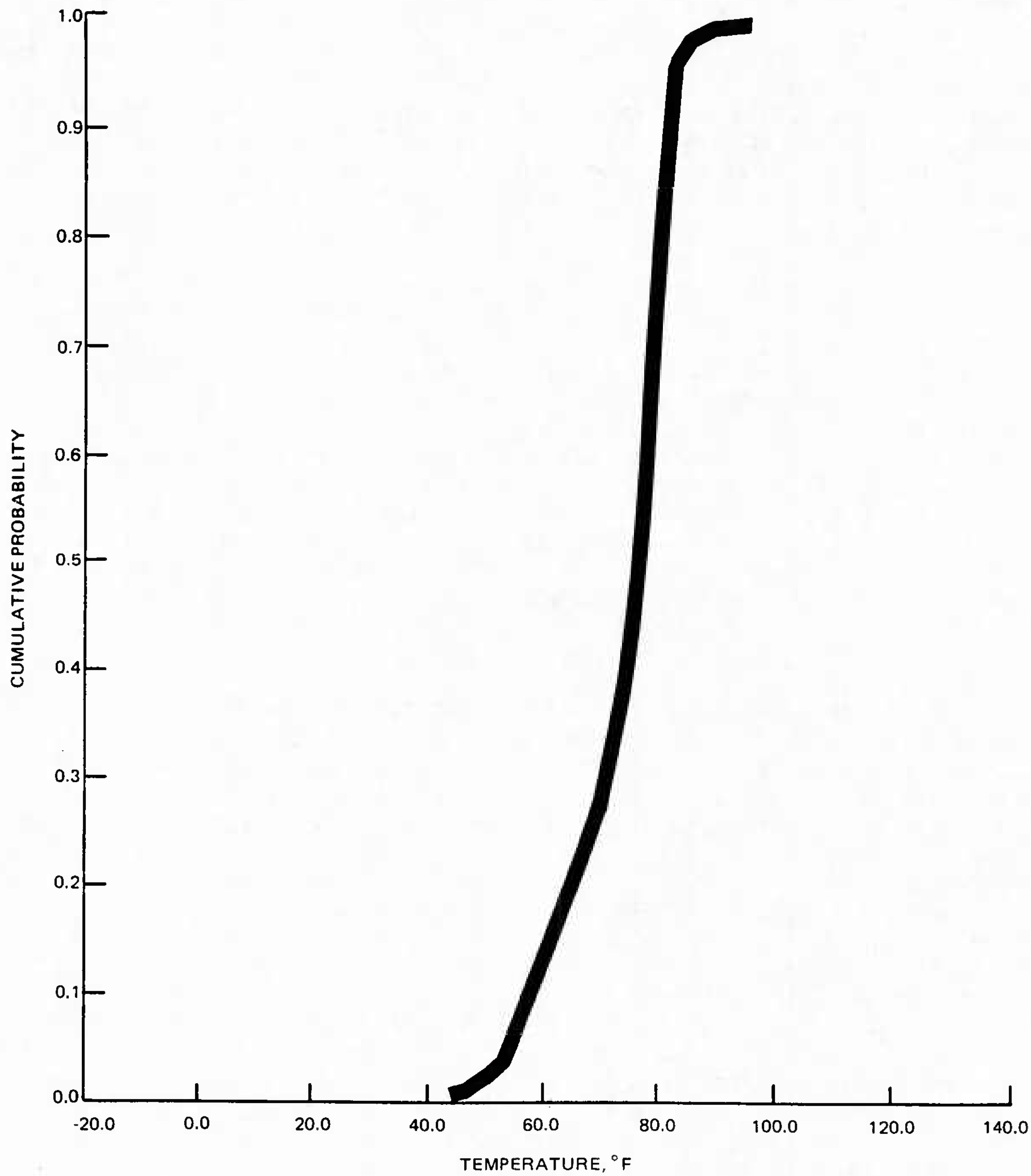

FIGURE 5. Data on Diesel-Powered Submarines.

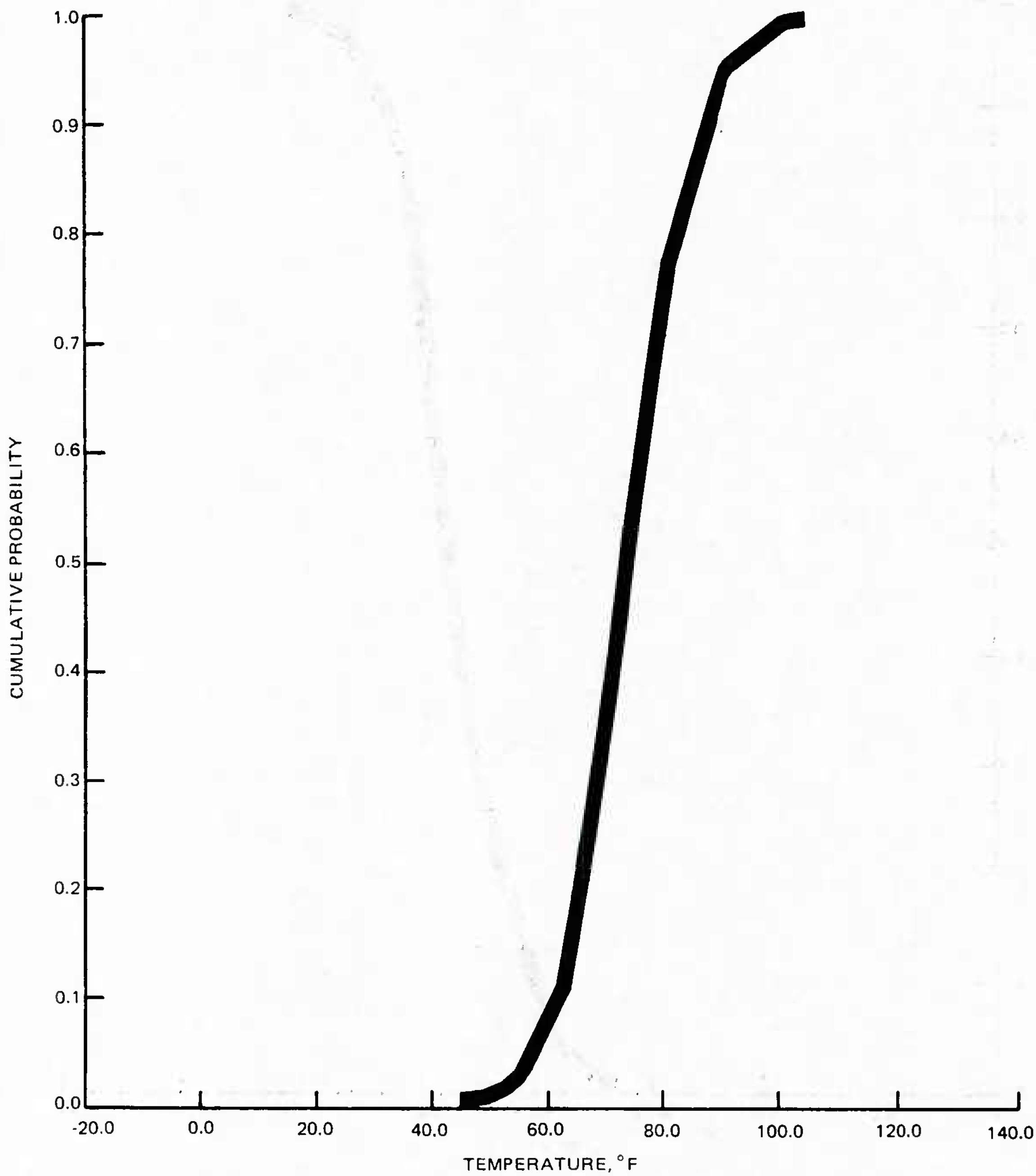

FIGURE 6. Data on Nuclear-Powered Submarines.

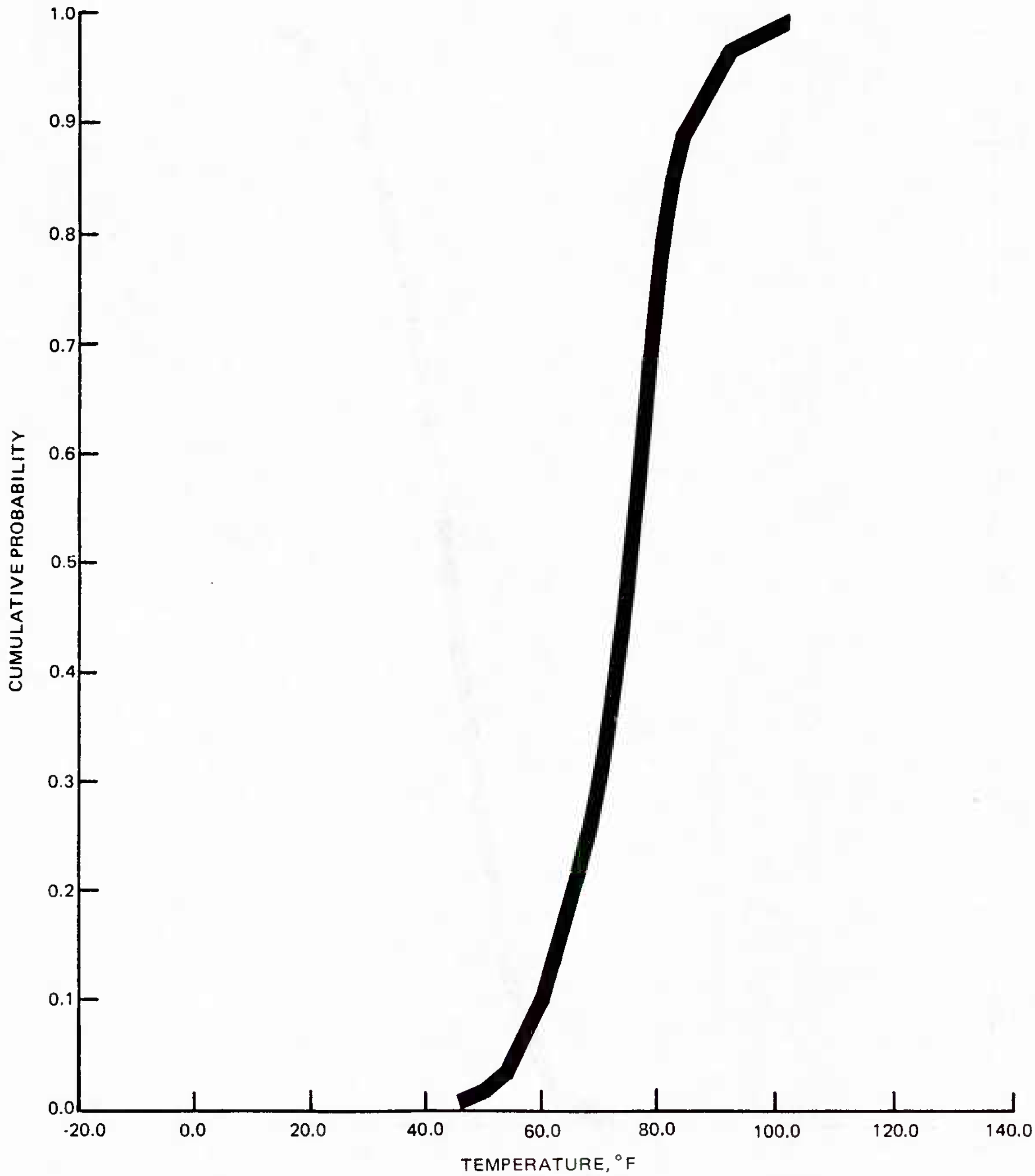

FIGURE 7. Combined Data for Both Diesel-Powered and Nuclear-Powered Submarines.

this figure, a statistical distribution can be inferred. The author has seen data displays such as Figure 7 used to set design criteria by directly using the two end point numbers as the maximum and the minimum. This is an acceptable procedure if a full understanding of the ramifications is understood. However, the author recommends that the exact data plot of Figure 7 be placed into a format that does not have end points. Then, any numbers chosen from the data display can be quantified with a value for risk of occurrence or assurance of not being exceeded.

The author notes that, in his judgment, the display of Figure 7 looks symmetrical enough and has about the right overall shape to be a rough approximation of a gaussian distribution. Therefore, he arbitrarily forced the data of Figure 7 into a gaussian format. To do this, he arbitrarily chose, from Figure 7, the temperature values that correspond closest to 0.0013 and 0.9987. These two temperature values were plotted on normal distribution paper, and joined by a straight line. The result is Figure 8. The line was drawn wide (as in all the figures), so that it would not be misconstrued that Figure 8 should be read too closely. However, for any uses to which these data may be put, the display of Figure 8 is more then adequate. (Any other technologist who disagrees with, or has a need not met by, Figure 8 is, of course, welcome to make his own assumptions and plot his own approximation from the data of Figures 5, 6, or 7. If the reader wants to see how accurately Figures 7 and 8 represent the data, he can plot the data on normal distribution paper and superimpose the line shown in Figure 8. The data can be found in Matsuda's work, Appendix A, Table A-1.)

CONCLUSIONS

It is helpful for environmental criteria and design purposes to depict data in the context of a continuous function. It is doubtful if any investigator ever really measures the "extreme" temperature situation in any finite measurement program. In fact, mid-range data are easily obtained. The only problem then is that users of the data who are concerned with "extremes" are left in a state of disappointment. Since the overwhelming amount of any data collected is moderate, then the central portion of any data display is probably quite accurate. The problem seems to be how to infer the "extremes" from any data collected. An engineering solution to this dilemma is provided in Figure 8. The chosen statistical distribution (somewhat arbitrarily) was gaussian.

Now, any distribution by definition orders the data from infinite to infinitesimal. In other words the distribution has no beginning and no end. In Figure 8 the line does not stop at the 0.01% risk line, but continues on. This is to alert the reader that this distribution is in fact endless. Now those concerned with the "extreme" can choose any temperature they want, and a commensurate risk (or assurance) value is provided.

For all rational purposes, the 0.01% cold to 0.01% hot risk portion of the distributed data is usually sufficient.

It can be seen in Figures 5 through 8 that, no matter what method of analysis is used, the temperatures inside any submarine will be temperate. The range of temperature shown is not indicative of any of the design values usually assigned to submarine ordnance and equipment.

Consequently, the thermal regime of equipment on board a submarine (if not self-heat generating) is moderate and temperate. It closely fits the comfort regime of man. Nowhere is there any indication that the temperatures of -65°F or 160°F have any meaning in the baseline for design temperature of submarine materiel or ordnance.

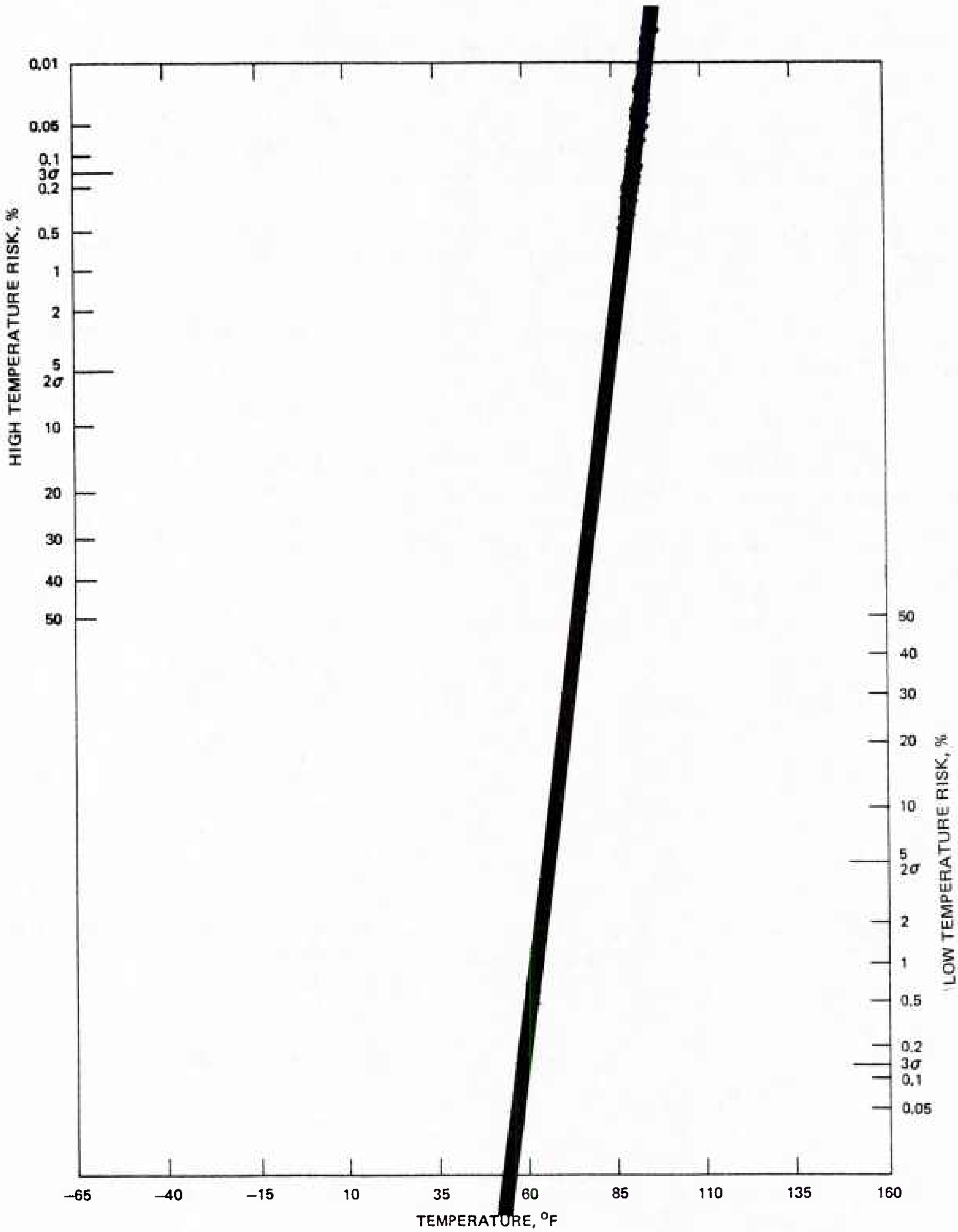

FIGURE 8. Gaussian Interpretation of the Combined Data for Both Diesel-Powered and Nuclear-Powered Submarines.

Appendix A

DATA HANDLING AND DATA DEFINITIONS

Submarine magazine and pyrotechnic locker temperature data as recorded in logbooks were keypunched onto cards and presorted per type of submarine and year of data from which they were taken.

These data cards were input through computer programs to yield the information presented in the sample (Table A-1). These data are defined as follows:

TAPE NO. is the tape number identifying the tape that the temperature data are written on.

FILE NO. is the file number of the tape that the data are written on.

IDENTIFICATION gives the type of submarines from which the data were obtained and the date the data were written on this tape.

CUMULATIVE PROBABILITY UP TO (TMIN AND TMAX) SUB I denotes

$$P_C(t_{min_j} \text{ and } t_{max_j}) = \sum_{j=-20°F}^{j=120°F} \frac{N(t_{min_j} \text{ and } t_{max_j})}{N_{t_{min_{total}}} + N_{t_{max_{total}}}}$$

where

$N(t_{min_j} \text{ and } t_{max_j})$ = the given frequencies of the daily minimum and maximum, combined, temperature data from -20 to 120°F at 1-degree intervals

$N_{t_{min_{total}}}$ = the total number of daily minimum temperature data

$N_{t_{max_{total}}}$ = the total number of daily maximum temperature data

TABLE A-1. Sample of Data on Diesel-Powered and Nuclear-Powered Submarines.

TAPE NO.: 3 FILE NO.: 4 IDENTIFICATION: DIESEL AND NUCLEAR POWERED ON TAPE 05/29/81

CUMULATIVE PROBABILITY UP TO (TMIN AND TMAX) SUB I

-20 DEG:	.0000	10 DEG:	.0000	40 DEG:	.0000	70 DEG:	.3774	100 DEG:	1.0000
-19 DEG:	.0000	11 DEG:	.0000	41 DEG:	.0000	71 DEG:	.3895	101 DEG:	1.0000
-18 DEG:	.0000	12 DEG:	.0000	42 DEG:	.0000	72 DEG:	.4324	102 DEG:	1.0000
-17 DEG:	.0000	13 DEG:	.0000	43 DEG:	.0000	73 DEG:	.4449	103 DEG:	1.0000
-16 DEG:	.0000	14 DEG:	.0000	44 DEG:	.0002	74 DEG:	.5071	104 DEG:	1.0000
-15 DEG:	.0000	15 DEG:	.0000	45 DEG:	.0007	75 DEG:	.5414	105 DEG:	1.0000
-14 DEG:	.0000	15 DEG:	.0000	46 DEG:	.0009	76 DEG:	.6361	106 DEG:	1.0000
-13 DEG:	.0000	17 DEG:	.0000	47 DEG:	.0021	77 DEG:	.6744	107 DEG:	1.0000
-12 DEG:	.0000	18 DEG:	.0000	48 DEG:	.0032	78 DEG:	.7371	108 DEG:	1.0000
-11 DEG:	.0000	19 DEG:	.0000	49 DEG:	.0048	79 DEG:	.7705	109 DEG:	1.0000
-10 DEG:	.0000	20 DEG:	.0000	50 DEG:	.0100	80 DEG:	.8334	110 DEG:	1.0000
-9 DEG:	.0000	21 DEG:	.0000	51 DEG:	.0115	81 DEG:	.8516	111 DEG:	1.0000
-8 DEG:	.0000	22 DEG:	.0000	52 DEG:	.0216	82 DEG:	.8707	112 DEG:	1.0000
-7 DEG:	.0000	23 DEG:	.0000	53 DEG:	.0244	83 DEG:	.8796	113 DEG:	1.0000
-6 DEG:	.0000	24 DEG:	.0000	54 DEG:	.0315	84 DEG:	.8924	114 DEG:	1.0000
-5 DEG:	.0000	25 DEG:	.0000	55 DEG:	.0375	85 DEG:	.8972	115 DEG:	1.0000
-4 DEG:	.0000	26 DEG:	.0000	56 DEG:	.0653	86 DEG:	.9109	116 DEG:	1.0000
-3 DEG:	.0000	27 DEG:	.0000	57 DEG:	.0723	87 DEG:	.9124	117 DEG:	1.0000
-2 DEG:	.0000	28 DEG:	.0000	58 DEG:	.0917	88 DEG:	.9420	118 DEG:	1.0000
-1 DEG:	.0000	29 DEG:	.0000	59 DEG:	.0996	89 DEG:	.9497	119 DEG:	1.0000
0 DEG:	.0000	30 DEG:	.0000	60 DEG:	.1221	90 DEG:	.9698	120 DEG:	1.0000
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4 DEG:	.0000	34 DEG:	.0000	64 DEG:	.1964	94 DEG:	.9852		
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PMS-407 (1)
1 Assistant Secretary of the Navy (Research, Engineering and Systems)
1 Commander in Chief, U.S. Pacific Fleet (Code 325)
1 Commander, Third Fleet, Pearl Harbor
1 Commander, Seventh Fleet, San Francisco
2 Fleet Analysis Center, Naval Weapons Station, Seal Beach, Corona
Code 862, GIDEP Office (1)
Technical Library (1)
2 Naval Academy, Annapolis (Director of Research)
2 Naval Air Test Center, Patuxent River (CT-252, Bldg. 405)
2 Naval Avionics Center, Indianapolis
R. D. Stone (1)
Technical Library (1)
1 Naval Ocean Systems Center, San Diego (Code 4473)
25 Naval Ordnance Station, Indian Head
Code 5A (1)
Code 5011C, A. P. Allen (1)
Code 5712A (1)
Code FS11C (1)
Code FS12A1 (1)
Code FS12A2 (1)
Code FS12A6 (1)
Code FS12B (1)
Code FS12D (1)
Code FS13 (1)
Code FS13A (1)
Code FS13C (1)
Code FS14 (1)
Code FS15A (1)
Code FS15B (1)
Code FS42 (1)
Code FS63 (1)
Code FS64 (1)
Code FS72 (1)
Code QA (1)
Code QA3 (1)
Code TDT, A. T. Camp (1)
J. Wiggin (1)
Technical Library (2)
1 Naval Postgraduate School, Monterey (Technical Library)
2 Naval Research Laboratory
Code 2600, Technical Library (1)
Code 5804, R. Volin (1)
3 Naval Ship Weapon Systems Engineering Station, Port Hueneme,
Code 5711, Repository (2)
Code 5712 (1)
13 Naval Surface Weapons Center, Dahlgren
Code D (1)
Code T (1)
Code TEE (1)
Code TI (2)
Code WXA, G. W. Allison (1)
Code WXO (1)
Code WXR (1)
Code WXS (1)
Code WXT (1)
Code WXV (1)
Jim Horten (1)
Technical Library (1)

9 Naval Surface Weapons Center, White Oak Laboratory, Silver Spring
    Code 702
        C. V. Vickers (1)
        V. Yarow (1)
    Code KM (1)
    Code LX-1, Doyle (1)
    Code NO, French (1)
    Code WE (2)
    Code XWF, Parker (1)
    Technical Library (1)
1 Naval Underwater Systems Center, Newport
1 Naval War College, Newport
2 Naval Weapons Evaluation Facility, Kirtland Air Force Base
    Code 210H, G. V. Binns (1)
    Code 70, L. R. Oliver (1)
2 Naval Weapons Quality Assurance Officer, Washington Navy Yard
    Director (1)
    Technical Library (1)
4 Naval Weapons Station, Colts Neck
    Code 70, C. P. Troutman (1)
    Naval Weapons Handling Center
        Code 805, R. E. Seely (1)
    Technical Library (2)
1 Naval Weapons Station, Concord (Technical Library)
5 Naval Weapons Station, Seal Beach
    Code QESX (1)
    Code QESX-3 (1)
    Environmental Test Branch (1)
    QE Department (1)
    Technical Library (1)
2 Naval Weapons Station, Yorktown
    Code 3032, Smith (1)
    Technical Library (1)
7 Naval Weapons Support Center, Crane
    Code 30331, Lawson (1)
    Code QETE (1)
    Code RD (1)
    NAPEC, J. R. Stokinger (1)
    S. Strong (2)
    Technical Library (1)
8 Pacific Missile Test Center, Point Mugu
    Code 1141, T. Elliott (1)
    Code 1143, C. V. Ryden (1)
    Code 1202, L. Matthews (1)
    Code 2133, F. J. Brennan (1)
    Code 2143, R. W. Villers (1)
    Code 3322, E. P. Olsen (1)
    Code 6862, Technical Library (1)
    Code 7379, Sparrow Office (1)
1 Theatre of Nuclear Warfare Project Office, PM-23, (Code TN-11)
1 Air Force Intelligence Service, Bolling Air Force Base (AFIS/INTAW, Maj. R. Lecklider)
2 Rome Air Development Center, Griffiss Air Force Base
    Code RCRM (1)
    Technical Library (1)
1 Sacramento Air Materiel Area, McClellan Air Force Base
1 Warner Robins Air Materiel Area, Robins Air Force Base (Technical Library)
3 Deputy Under Secretary of Defense, Acquisition Management
    Director, Materiel Acquisition Policy, J. A. Mattino,
    3E 144 (1)
    Deputy Director, Standardization & Support, Col. T. A.
    Musson, 2A318 (2)

2 Deputy Under Secretary of Defense, Research and Advanced Technology
   Engineering Technology
      Director, Engineering Technology (1)
      R. Thorkildsen (1)
12 Defense Technical Information Center
3 Department of Defense, Explosives Safety Board, Alexandria
1 Director, Defense Test & Evaluation (Deputy Director, Test Facilities & Resources, W. A. Richardson, 3D1043A)
3 Armament/Munitions Requirements & Development (AMRAD) Committee (2C330, Pentagon)
2 DLA Administrative Support Center (Defense Materiel Specifications and Standards Office)
   J. Allen (1)
   D. Moses (1)